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A Vision of the Future for Large-Scale Carbon Dioxide Capture and Storage: Findings from Phase 2 of the Global Energy Technology Strategy Project

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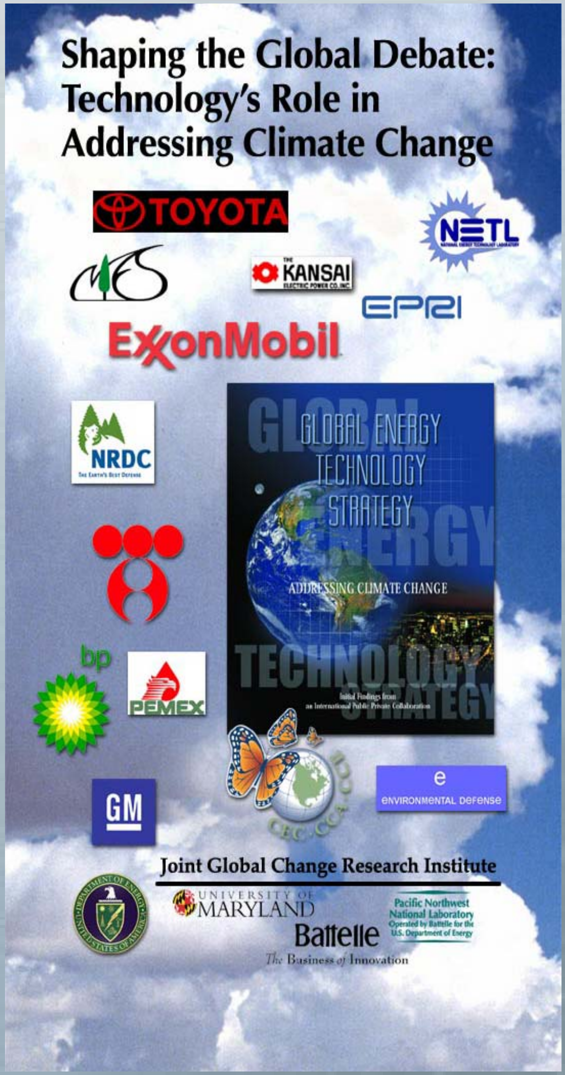
The Global Energy Technology Strategy Project

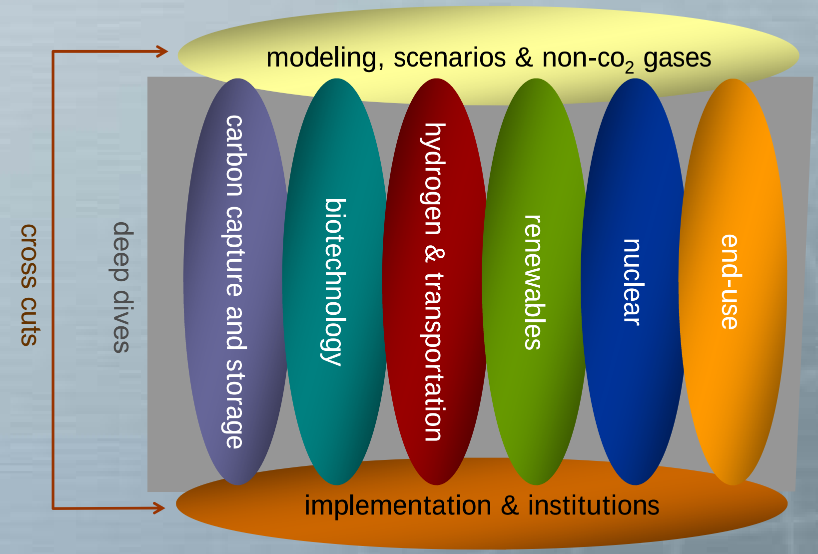
- Unique, multinational, public/private sector research program launched in 1998 to better understand the role of technology in addressing climate change.

- First GTSP summary report released in 2001 at a special session at COP6 in the Hague which articulated the need for a multi-pronged, systematic strategy for addressing climate change that must include four key components:
    - Adaptation
    - (Global) Technology Development and Deployment
    - Emissions Mitigation
    - Resolving the Scientific Uncertainty.



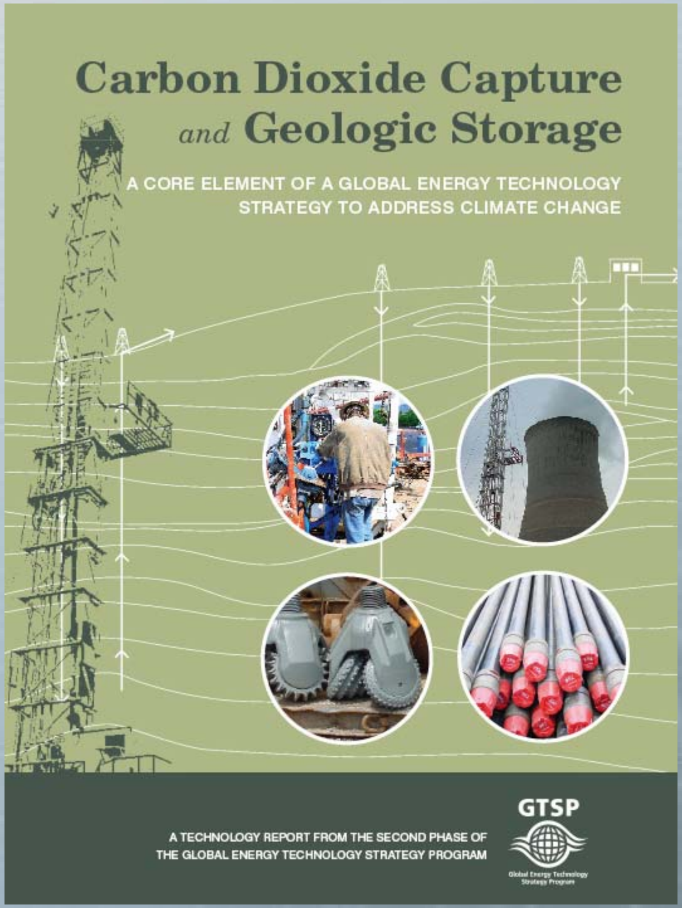
GTSP Phase I: Summary Conclusions

- Fundamental changes in the energy system are necessary to stabilize atmospheric concentrations of GHGs.
- Successful development and deployment of new technologies can significantly reduce the cost of achieving any stabilization target.
- Incremental improvements in technology help, but will <u>not</u> by themselves lead to stabilization.
- Six key technologies were identified that are needed to fill the "Stabilization Gap."



GTSP Phase II Capstone Report on Carbon Dioxide Capture and Storage

- CCS technologies have tremendous potential value for society.
- CCS is, at its core, a climate-change mitigation technology and therefore the large-scale deployment of CCS is contingent upon the timing and nature of future GHG emission control policies.
- The next 5-10 years constitute a critical window in which to amass needed real-world operational experience with CCS systems.
- The electric power sector is the largest potential market for CCS technologies and its potential use of CCS has its own characteristics that need to be better understood.
- Much work needs to be done to ensure that the potential large and rapid scale-up in CCS deployment will be safe and successful.

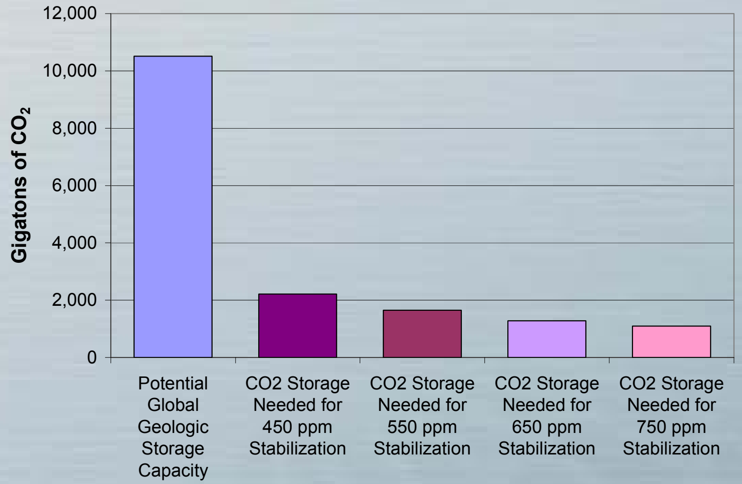


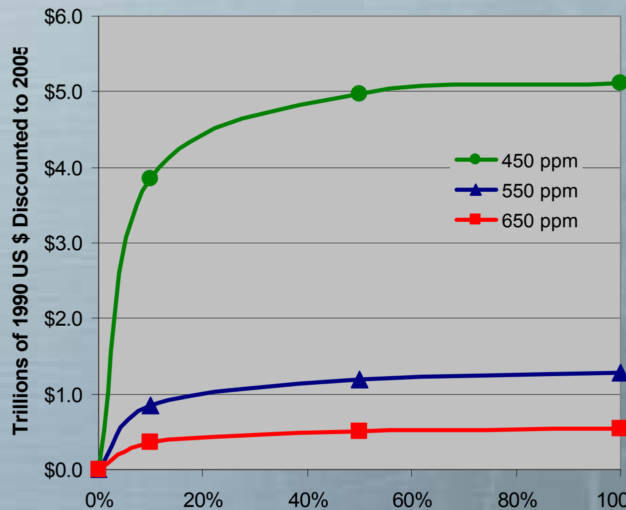
Macro View of the Role of CCS

- What is the potential scale of CCS deployment?
  - Is there enough geologic storage capacity?
    - What's the value of CCS deployment?

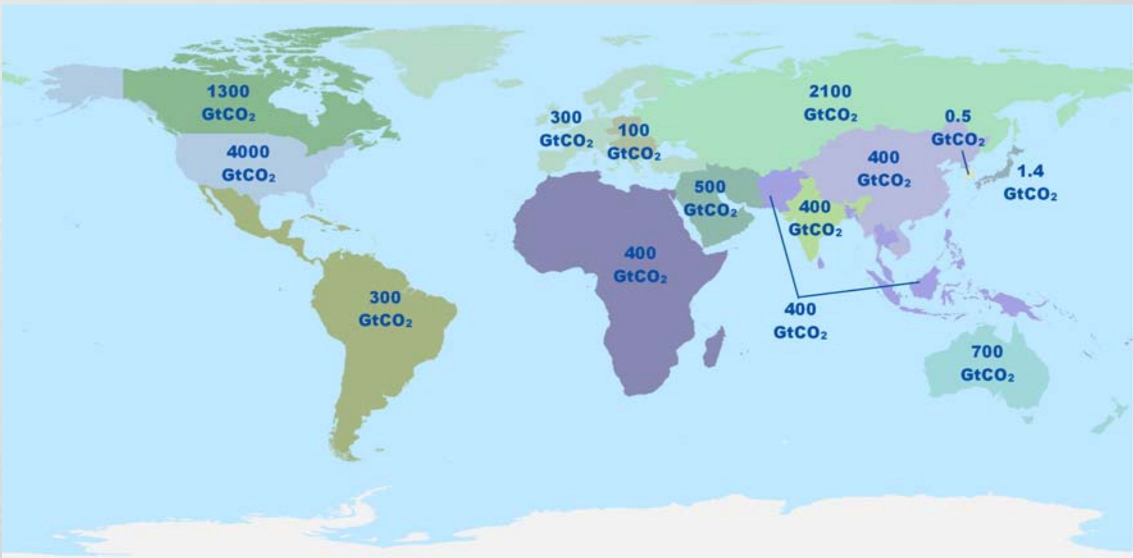
Global CO_2 Storage Capacity:
Abundant and Potentially Valuable Natural Resource

- Assuming that society has a broad portfolio of carbon management options at its disposal:
  - There appears to be sufficient global theoretical storage capacity to easily accommodate the demand for CO_2 storage for stabilization scenarios ranging from 450-750ppmv.
- Even though there is no definitive answer as to what the total global theoretical capacity is and what fraction is viable:
  - CCS still has potentially huge value to society even if only a fraction of current estimates of potential global geologic CO_2 storage capacity is available.



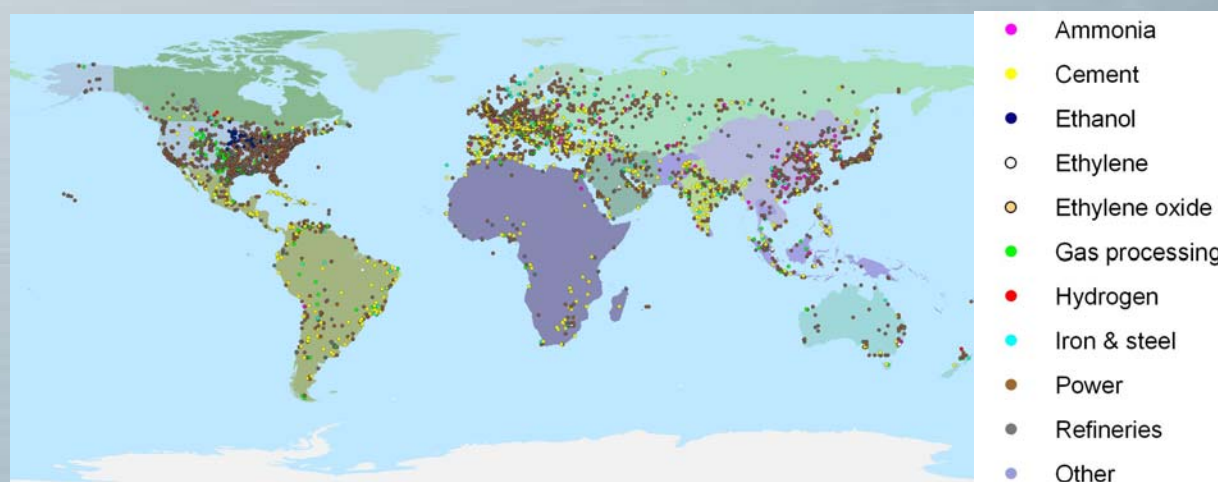


Global CO_2 Storage Capacity
A Very Heterogeneous Natural Resource



- 11,000 $GtCO_2$ of potentially available storage capacity
- U.S., Canada and Australia likely have sufficient CO_2 storage capacity for this century
- Japan and Korea's ability to continue using fossil fuels likely constrained by relatively small domestic storage reservoir capacity

- ~8100 Large CO_2 Point Sources
- 14.9 $GtCO_2$/year
- >60% of all global anthropogenic CO_2 emissions



Global CO_2 Storage Capacity:
Take Home Messages

- Geologic CO_2 storage reservoirs, like many other natural resources, are heterogeneous in quality or distribution.
  - Some regions have the potential to use CCS for a very long time and likely with fairly constant and possibly declining costs.
  - In other regions, CCS appears to be more of a transition technology.
  - Simply knowing whether a given region has more theoretical CO_2 storage capacity or more “value-added” CO_2 storage potential is not a significant predictor of the extent to which CCS technologies will be deployed as a central means of reducing CO_2 emissions.
  - On the other hand, *a priori* knowledge of a lack of or severely constrained CO_2 storage potential in a region likely does suggest fewer options for reducing CO_2 emissions.
- A near-term high-priority research task is to survey candidate CO_2 storage reservoirs in the U.S. and in other key nations (e.g., China and India) as the availability of this resource directly impacts the likely evolution of a region’s future energy infrastructure.

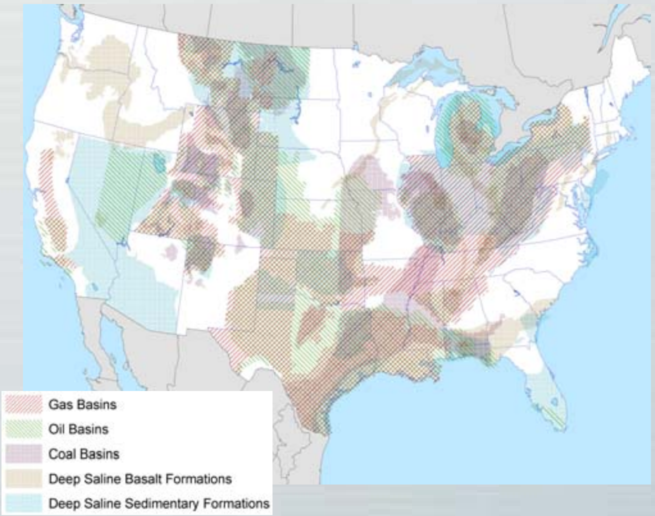
Micro View of the Role of CCS

How will CCS deploy across the U.S. economy?

How will CCS work within the U.S. electric utility industry?

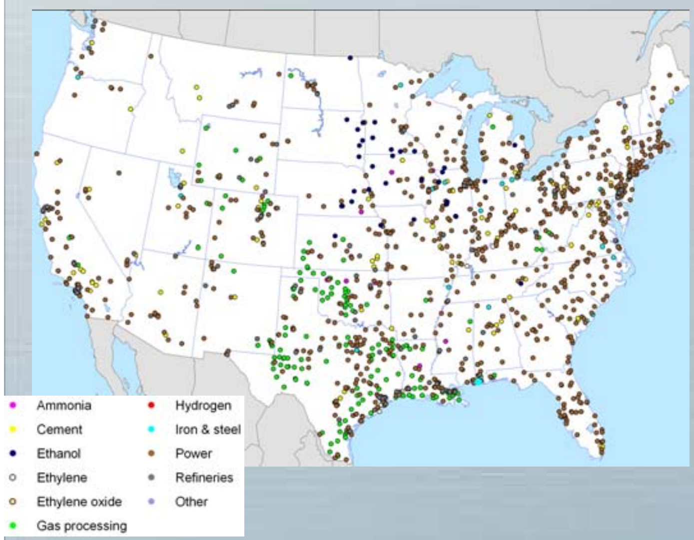
CCS Deployment Across the US Economy

Large CO_2 Storage Resource and Large Potential Demand for CO_2 Storage



3,900+ $GtCO_2$ Capacity within 230 Candidate Geologic CO_2 Storage Reservoirs

- 2,730 $GtCO_2$ in deep saline formations (DSF) with perhaps close to another 900 $GtCO_2$ in offshore DSFs
- 240 Gt CO_2 in on-shore saline filled basalt formations
- 35 $GtCO_2$ in depleted gas fields
- 30 $GtCO_2$ in deep unmineable coal seams with potential for enhanced coalbed methane (ECBM) recovery
- 12 $GtCO_2$ in depleted oil fields with potential for enhanced oil recovery (EOR)

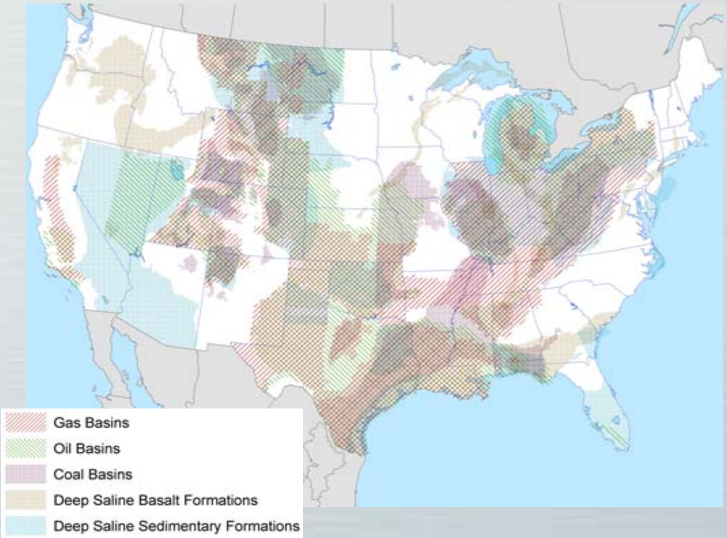


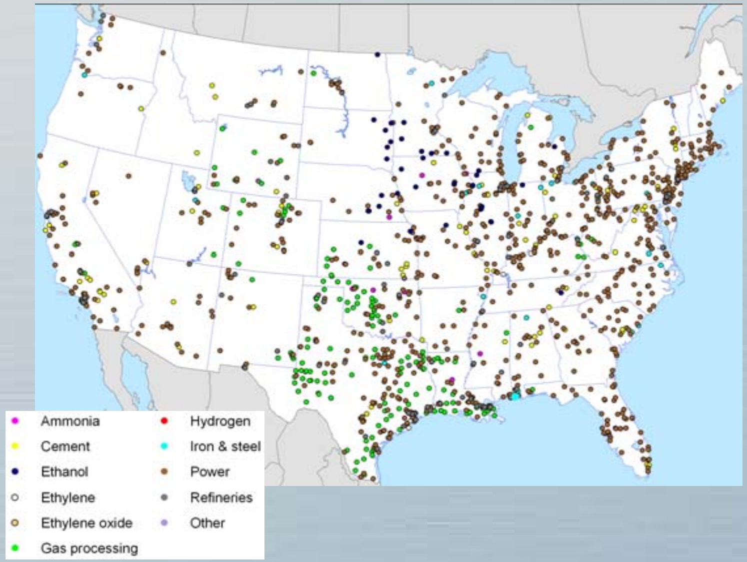
1,715 Large Sources (100+ $ktCO_2$/yr) with Total Annual Emissions = 2.9 $GtCO_2$

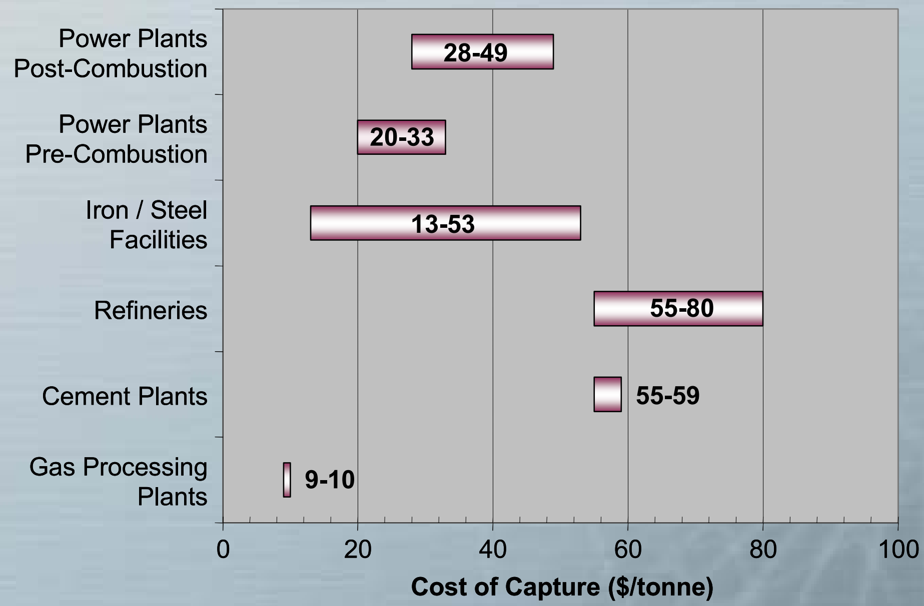
- 1,053 electric power plants
- 259 natural gas processing facilities
- 126 petroleum refineries
- 44 iron & steel foundries
- 105 cement kilns
- 38 ethylene plants
- 30 hydrogen production
- 19 ammonia refineries
- 34 ethanol production plants
- 7 ethylene oxide plants

CCS Deployment Across the US Economy

No uniform “CCS” technology. No homogenous market.







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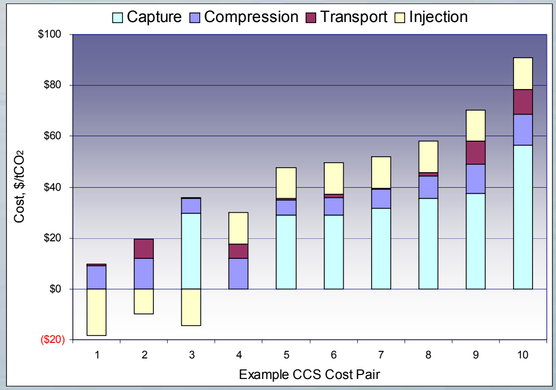
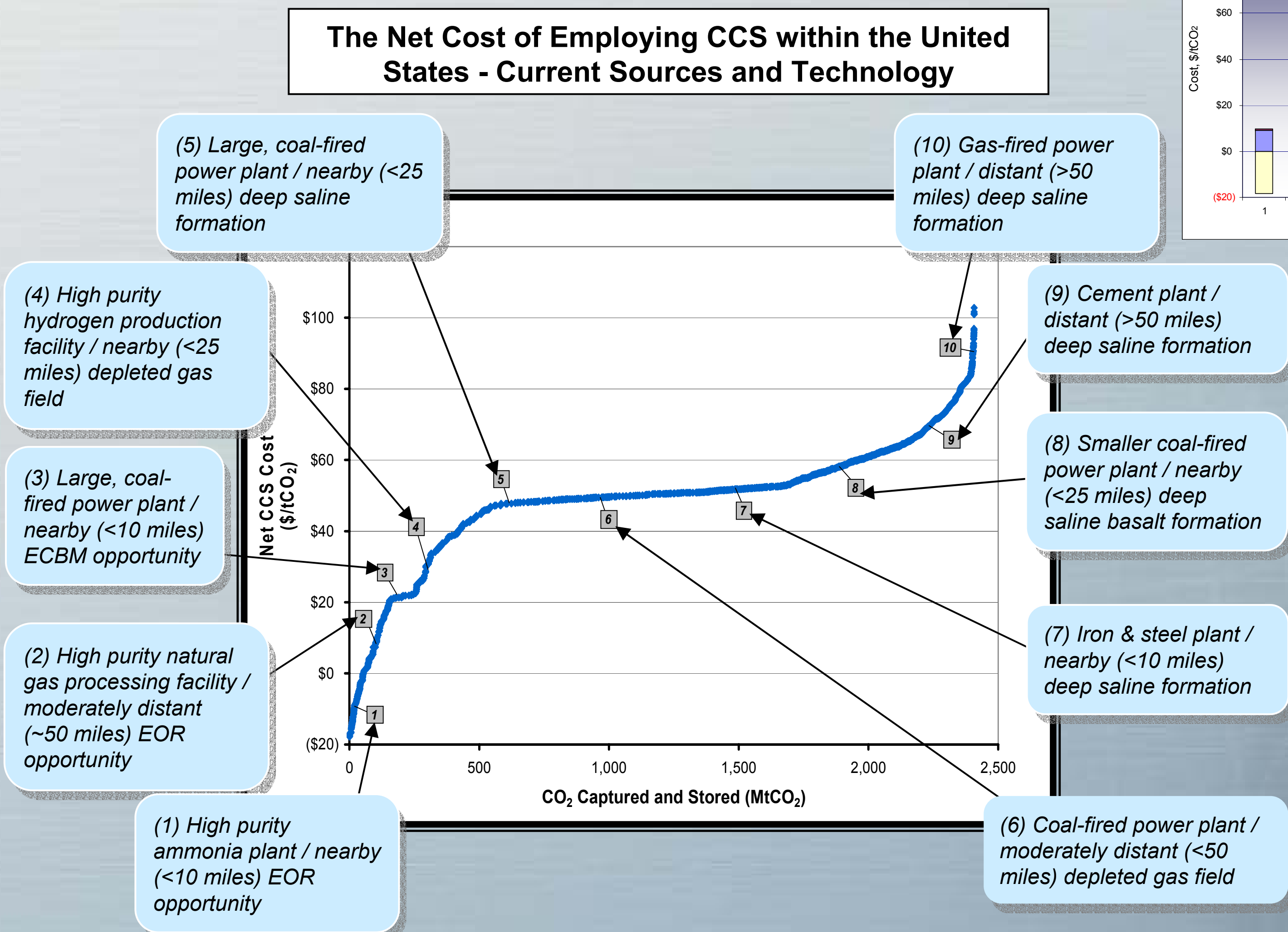
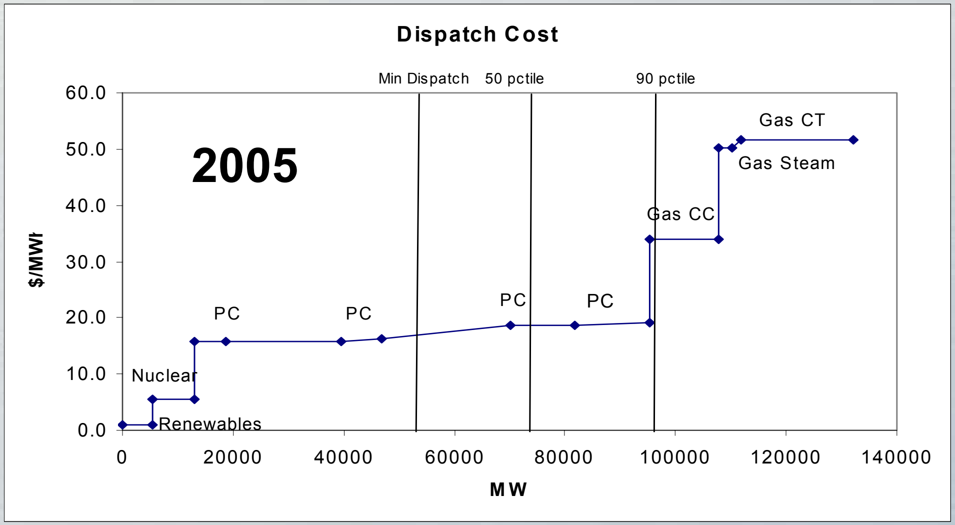
CCS Deployment Across the US Economy

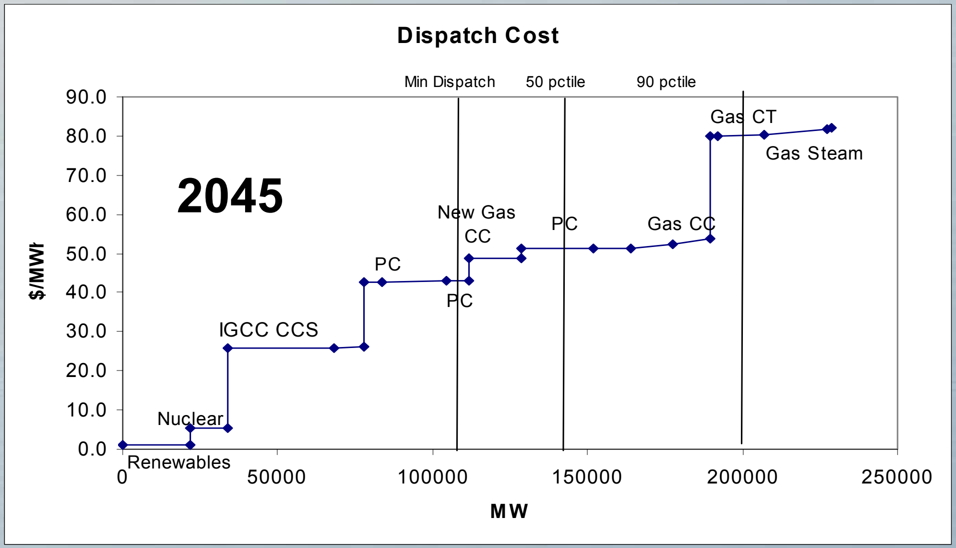
Differentiated CCS Adoption Across Economic Sectors





CCS Deployment by Electric Utilities
IGCC+CCS a Key to Decarbonizing Baseload Power





- In 2005, conventional fossil-fired power plants were the predominant means of generating competitively priced electricity.

- However, given today's and (likely) tomorrow's higher natural gas prices and the imposition of a hypothetical binding greenhouse gas control policy,
  - IGCC+CCS becomes -- in some regions of the U.S. -- the dominant means of generating low-carbon *baseload* electricity.
  - The overwhelming criteria for siting a CCS-enabled power plant will relate to things like total reservoir capacity and allowable, safe rates of injection and not whether there is "buyer for CO_2."
  - Deep saline formations will be the CO_2 storage reservoir workhorse for the U.S. and many other countries.

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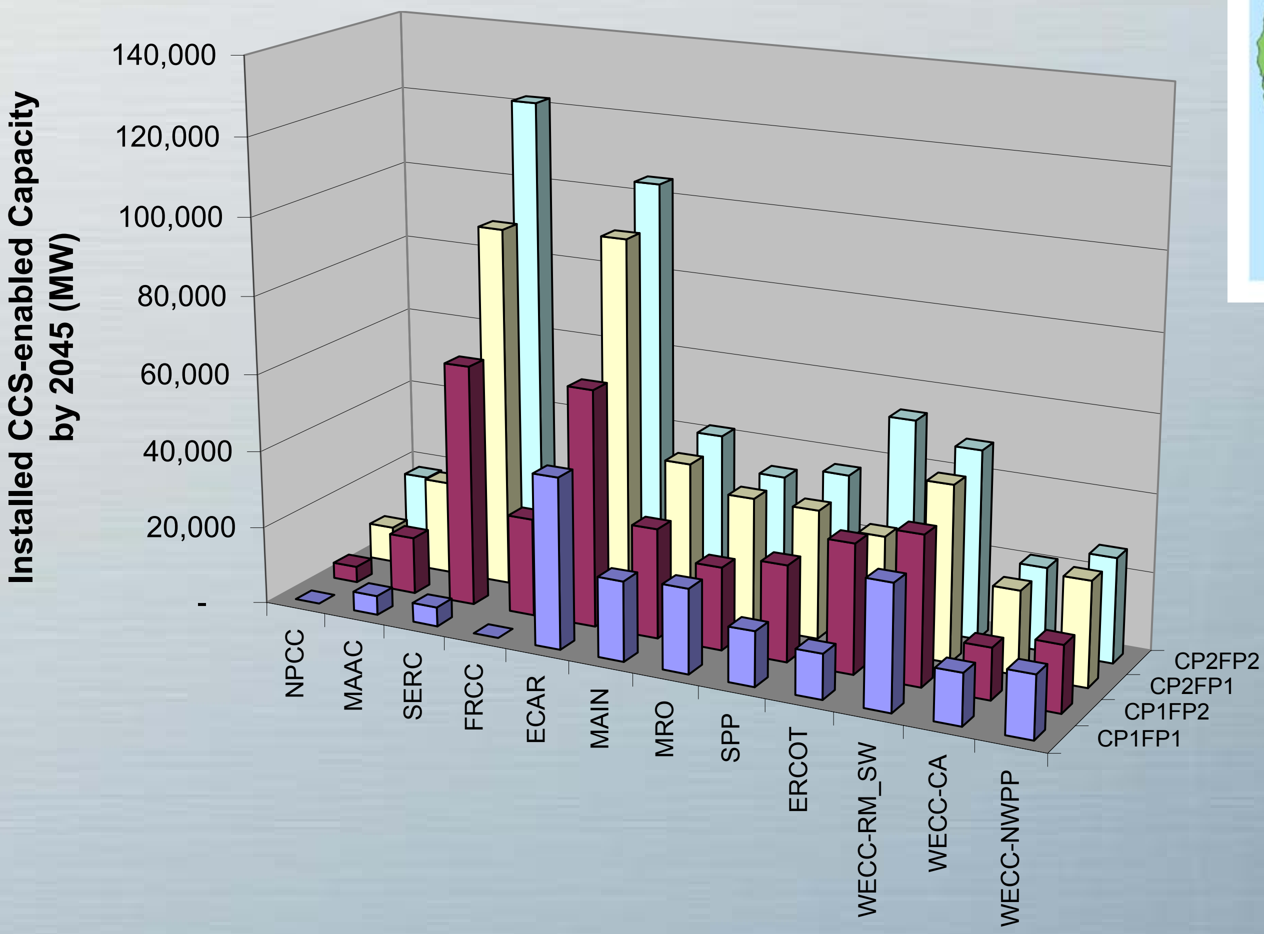
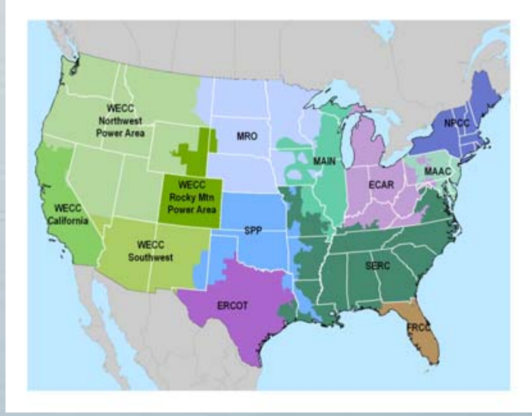
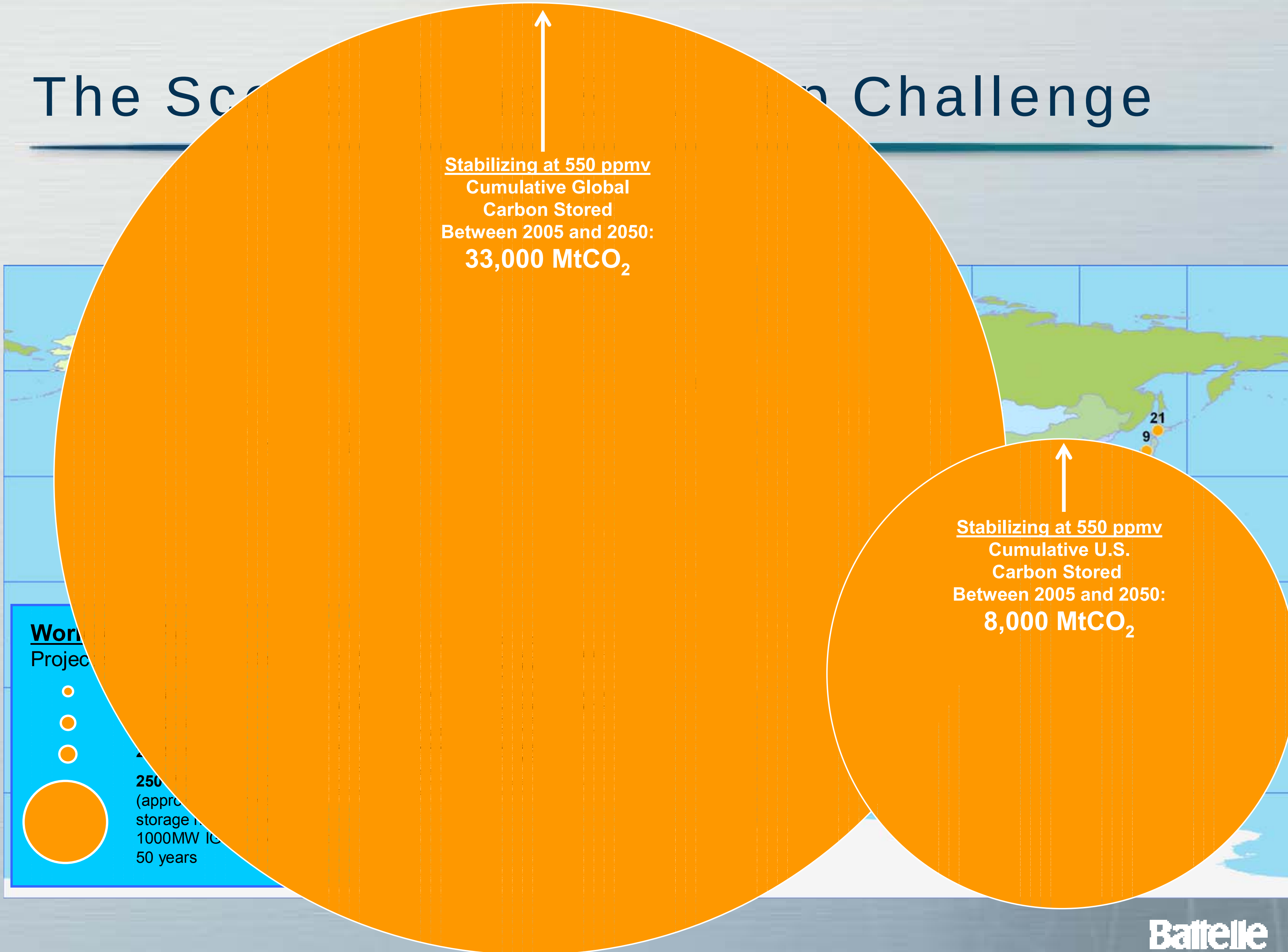




Regional utilization of IGCC+CCS can be significantly influenced by carbon tax and natural gas price *as well as regional geology.*

The Sc… Challenge



Translating the Potential of CCS into a Cornerstone of a Low-Carbon Global Economy…

- Harnessing the potential of CCS to reduce the cost of addressing climate change will require that CCS technologies:
  - Work
  - Make Economic Sense
  - Are Accepted and Trusted, and Ordinary.

- It is important to realize that we are in the *earliest stages* of the deployment of CCS technologies. Much hard work remains to fulfill the potential promise of CCS technologies for addressing climate change.

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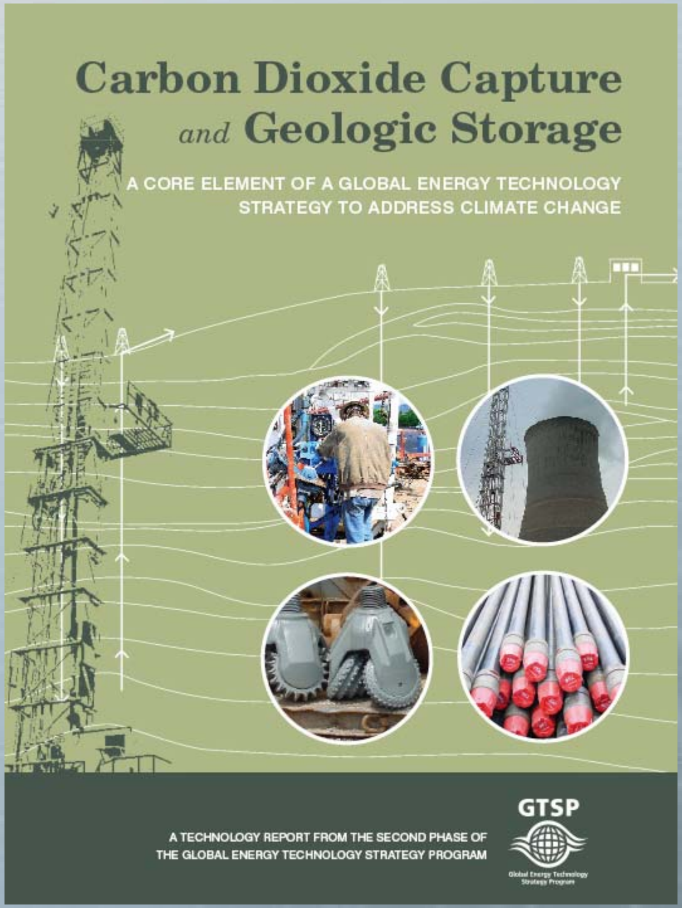

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